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QUANTITATIVE MINERALOGY OF CHROMITE ORE FROM BIRD RIVER, MANITOBA

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QUANTITATIVE MINERALOGY OF CHROMITE ORE FROM BIRD RIVER, MANITOBA

by

J.M.D. Wilson, W. Petruk and R. Pinard**ABSTRACT**

A liberation study of a crushed ore sample from the Chrome property of the Bird River deposit in Manitoba showed that the concentrate obtained by physical mineral beneficiation methods would be of low grade and poor recovery. A liberation of only 70% at a grind of 80% -27 μm was predicted. Chromium-to-iron ratios of pure Bird River Cr-rich chromite vary from 1.2 to 1.8, and average 1.4. Since the Cr-rich chromite is intimately associated with the Fe-rich chromite, which has an average ratio of .62, and is not readily liberated, it is unlikely that a Cr:Fe ratio in excess of 1.5 would be achieved.

Keywords: Chromite, Liberation, Mineral Processing, Mineralogy, Bird River, Image Analysis

**ANALYSE QUANTITATIVE D'UN MINÉRAI DE CHROME
PROVENANT DE BIRD RIVER, MANITOBA**

par

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RÉSUMÉ

D'après les résultats d'une étude portant sur la libération d'un échantillon de minéral concassé provenant du gisement de chrome de Bird River au Manitoba, le concentré que l'on obtiendrait par des méthodes physiques d'enrichissement des minéraux serait de qualité inférieure et le taux de récupération serait faible. Une libération de 70 % seulement est prévue quand 80 % des grains passent la maille de -27 μm . Dans la chromite pure à haute teneur en Cr, les taux de chrome par rapport à ceux du fer varient de 1,2 à 1,8, et le taux moyen est de 1,4. Comme la chromite à haute teneur en chrome (Cr) est étroitement associée à la chromite riche en fer (Fe) dont la teneur moyenne est de .62 et qui n'est pas libérée facilement, un rapport Cr:Fe excédant 1,5 semble peu probable.

Mots-clé : chromite; libération; traitement des minéraux; minéralogie; Bird River; analyse d'image.

INTRODUCTION

A sample from the Chrome property of the Bird River chromite deposit, Manitoba, is being investigated by the Ore Dressing Section of CANMET to produce by gravity, magnetic and flotation methods a chromite concentrate suitable for metallurgical end-use. The composition of the concentrate determines its allocation within the three general markets for chromite: metallurgical, refractory and chemical (including foundry). The chromium industry recognizes three grades of chromite product (Table 1) each of which is preferred by a specific market (1).

The first two phases of the investigations, performed under contract by Lakefield Research (2), consisted of mineralogical and pilot plant testwork. The results indicated that a concentrate for ferrochromium production would not be obtained because of the following mineralogical restrictions. These, according to Andrews and Jackman (2) are:

1. Low Cr:Fe ratio in the chromite;
2. Presence of Fe-rich rims on the chromite particles; and
3. Fine liberation size of the chromium grains (95% $-150\ \mu\text{m}$).

A subsequent feasibility study, however, has indicated that the Bird River product may be used on-site to make stainless steel (3). The purpose of the present study was to conduct a thorough quantitative mineralogical investigation on a representative sample of the Chrome ore to help elucidate chromite recovery problems.

METHOD OF INVESTIGATION

A 2-kg blended head sample of $-3.35\ \text{mm}$ crushed ore from the Chrome property was received from the Ore Dressing Section. This sample was sieved at $1.18\ \text{mm}$, $600\ \mu\text{m}$, $425\ \mu\text{m}$, $300\ \mu\text{m}$, $212\ \mu\text{m}$, $150\ \mu\text{m}$, $106\ \mu\text{m}$, $75\ \mu\text{m}$, $53\ \mu\text{m}$ and $38\ \mu\text{m}$. One polished section was made of each sieved fraction as well as one thin section of the $+1.18\ \text{mm}$ fraction. Each section was examined using an ore microscope and by the MP-SEM-IPS image analysis system consisting of a scanning electron microscope to produce an image, an energy dispersive X-ray

analyzer to identify the minerals and an image analyzer to measure the mineral quantities and liberations. A portion of the head sample was analyzed using an X-ray diffractometer to help identify the major gangue minerals. One thin section of the coarsest fraction was also examined using the transmitted-light microscope. In addition, the chemical composition of the chromium-bearing phases in one sieve fraction was determined by electron microprobe using wavelength dispersive X-ray analysis.

CHROMITE MINERALOGY

The minerals identified in the sample are listed in Table 2. Chromite is abundant and occurs mainly as coarse rounded grains (100 to 300 μm diam) in a matrix of serpentine and chlorite (Fig. 1). Most of these chromite grains are zoned from a Cr-rich core to an Fe-rich rim. The Cr-rich cores show a gradual decrease in chromium content from the grain centres toward the rims with a concomitant increase in iron content (Fig. 2). Some of these grains contain a round core consisting of one or more of the silicate gangue minerals (Fig. 1). Other chromite grains are heterogeneous with patches of various chromium contents (Fig. 3). The chromite grains with the highest chromium content were always found in this type of heterogeneous or mixed particle. All the chromite grains examined had a variable chromium content. Of the few magnetite grains that were examined chromium was found in all. The magnetite usually occurs as skeletal intergrowths and small disseminations in the silicate gangue minerals (Fig. 1). However, one probe analysis indicated that the Fe-rich rims of some chromite grains may be magnetite.

COMPOSITION OF CHROMIUM-BEARING PHASES

Results of the microprobe analyses are given in Table 3. These results may be grouped according to their total Fe content, here expressed as FeO. The compositional ranges of each group are summarized in Table 4. They show that the Cr-rich chromite contains 41.0 to 54.0 wt % Cr_2O_3 and averages 45.4 wt %, based on 19 analyses. The Cr/Fe ratio varies from 1.2 to 1.8, and

averages 1.4. The Fe-rich chromite has a Cr_2O_3 content of 38.8 wt % and an average Cr/Fe ratio of 0.62.

MINERAL QUANTITIES

Table 2 shows the mineral quantities determined for each sieve fraction and a calculated mineral composition for the head sample. The data also show that Cr-rich chromite makes up 78 to 98% of the chromium-bearing phases in the various sieve fractions. Therefore it is reasonable to consider that about 90% of the chromium-bearing phases is Cr-rich chromite. The remainder is probably distributed equally between Fe-rich chromite and magnetite. The average composition of the chromium-bearing phases, assuming equal proportions of Fe-rich chromite and magnetite, is calculated at 42.9 wt % Cr_2O_3 and 33.6 wt % FeO with a Cr/Fe ratio of 1.1. If the assumed proportion of magnetite is disregarded the average chromite composite is calculated as 45.0 wt % Cr_2O_3 and 30.5 wt % FeO with a Cr/Fe ratio of 1.3.

LIBERATION

Mineral liberation is determined by discriminating between the free and locked chromite grains. The locked grains are then classified according to the areal fraction, expressed as a per cent, of the host particle which the chromite grain occupies. The classes are defined from 0 to 99.99% in arbitrary steps of 10% (i.e., 0-10%, 10-20%, etc.). Table 5 shows the liberation percentages of the chromite phases, expressed as total chromite (Cr-rich + Fe-rich) in each sieved fraction.

The results are plotted in Fig. 4 from which the minimum grind and the expected liberation can be interpreted. The observed liberation for the +90% class of chromite of the +48 mesh fraction is considered an anomaly because a similar peak is not observed in the plot of the free chromite. The inflection point at 35 mesh in the liberation curve for particles containing more than 90% chromite indicates that the minimum grind (a grind which produces a product where 50% of the chromite is in particles that contain more than 90 vol % chromite) is approximately 100% -35 mesh (425 μm).

The liberation for this grind may be calculated by first estimating the size distribution of ground material from the proportions of the weights of the -425 μm sieve fractions in Table 5 and multiplying them by the liberation values from Fig. 1. This gives a liberation of 49.4%. The composition was calculated for a hypothetical concentrate that would be obtained from material finer than 425 μm , assuming 100% recovery of the +90% class of chromite particles. The percentage of completely free chromite was subtracted and the remainder of the chromium was assumed to be in particles consisting of 96% chromite. The chromite composition was assumed to be that of Cr + Fe - rich chromite. The calculated concentrate grade is 43.6% Cr_2O_3 with 29.6% FeO. Chromite liberation for a grind of 100% -38 μm is 70% of the chromite in particles that contain more than 90% chromite. Again assuming 100% recovery the hypothetical composition is calculated as 44.2 wt % Cr_2O_3 and 29.9 wt % FeO.

CONCLUSIONS

1. The liberation data in Table 5 show that a substantial proportion of the chromite-bearing particles finer than 425 μm contain more than 90% chromite. It is interpreted that if the ore is ground to 80% -300 μm then 50% of the chromite would be in such particles. The data also show that further grinding would not significantly increase chromite liberation. Even at a grind of 80% -27 μm (equivalent to 100% -38 μm) only 70% of the chromite would be in particles that contain more than 90% chromite.
2. The Cr/Fe ratio for the Cr-rich chromite ranges from 1.2-1.8 and averages 1.4 (Table 4). This indicates that, with perfect liberation of this phase, it might be theoretically possible to produce a concentrate that meets minimum specifications, i.e., Cr/Fe of 1.5.
3. As the two chromite phases and some of the magnetite are intimately associated, it is not possible to separate these minerals by practical physical methods. Therefore, in recovering the Cr-rich chromite, the

Fe-rich chromite and some of the magnetite must also report to the concentrate. Assuming perfect liberation and recovery of these three chromium-bearing phases taken together the expected Cr/Fe ratio in the concentrate would be 1.1. Assuming perfect liberation and recovery of only the two chromite phases the Cr/Fe ratio in the concentrate would be 1.3.

REFERENCES

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2. Andrews, P.R.A. and Jackman, I. "Laboratory and pilot-plant beneficiation of chromite ore from Bird River, Manitoba"; Division Report MSL 87-8 (OP&J); CANMET, Energy, Mines and Resources Canada; 1987.
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Table 1. Classification of chromite by composition

Class of ore	Composition	Market
High-Cr	Cr_2O_3 45-56% Cr:Fe>2.5:1	Metallurgical
High-Fe	Cr_2O_3 42-64% Cr:Fe=1.5-2.0:1	Chemical Metallurgical Foundry
High-Al	Cr_2O_3 33-38% Cr:Fe=2.0-2.5:1 Al_2O_3 22-34%	Refractory

Table 2. Mineral quantities in head by sieve fraction (wt % retained)

Mineral type	Sieve fraction (μm)											
	+1180*	+600*	+425	+300	+212	+150	+106	+75	+53	+38	-38	Head
Quartz	.2	.1	tr	.1	tr	tr	nil	tr	tr	tr	.4	.8
Serpentine + chlorite	44.1	12.3	4.0	3.6	1.1	1.3	.8	.8	.8	.6	2.4	71.8
Ca-Mg-Fe silicate	2.2	.6	.2	tr	.2	.2	.3	.1	.1	.1	.1	4.1
Cr-rich chromite	9.3	2.6	.8	1.8	2.6	1.5	.7	.5	.3	.1	.5	20.7
Fe-rich chromite + magnetite	1.6	.5	.1	tr	.1	.1	.1	.1	tr	tr	tr	2.6
Violarite	nil	nil	nil	nil	nil	nil	tr	nil	nil	nil	nil	tr
Chalcopyrite + millerite	tr	tr	nil	tr	nil	nil	nil	nil	nil	nil	nil	nil
Sphalerite + barite	nil	nil	nil	nil	nil	nil	nil	nil	nil	tr	nil	tr
Pyrite	nil	nil	nil	nil	nil	nil	nil	nil	nil	tr	nil	tr
TOTAL	57.4	16.1	5.1	5.5	4.0	3.1	1.9	1.5	1.2	.8	3.4	100.0
Cr-rich chromite of total Cr-minerals (wt %)	85	85	86	98	97	94	92	88	89	78	96	

*Mineral proportions of these fractions assumed same as -600 +425 fraction.

Table 3. Electron microprobe results (wt %)*

Spot	Cr ₂ O ₃	FeO	Al ₂ O ₃	MgO	Location
A-1	45.4	28.4	16.8	8.1	Core
A-3	39.9	53.5	1.6	0.8	Rim
A-4	43.1	27.7	18.4	8.1	Core
A-5	44.0	30.6	17.2	7.1	Core
A-6	1.9	92.8	nil	0.2	Magnetite (rim)
A-7	0.1	93.1	nil	nil	Magnetite
A-10	44.8	27.7	16.6	9.0	Core
A-11	44.0	31.7	16.7	6.1	Core
B-2	51.1	25.6	15.5	6.8	Mixed
B-2A	42.1	28.4	20.0	7.7	Mixed
B-3	54.0	27.1	12.0	5.8	Mixed
B-4	42.2	27.6	19.8	8.2	Core
B-5	50.6	25.8	16.1	6.9	Mixed
B-6	0.4	93.8	0.1	nil	Magnetite
B-7	53.7	27.4	13.2	5.0	Mixed
C-1	44.1	29.9	17.3	7.0	Core
C-2	44.2	32.1	17.2	4.6	Core
C-3	39.2	54.5	1.1	0.5	Rim
C-4	41.0	29.2	20.5	7.2	Core
C-5	35.9	56.1	1.6	0.8	Rim
D-1	42.1	26.5	20.4	8.9	Core
D-2	43.0	28.0	19.6	8.7	Core
D-3	45.3	32.3	15.7	5.2	Core
D-4	43.7	32.3	15.8	4.8	Core
D-5	40.1	54.0	0.3	0.7	Rim
D-6	2.0	90.6	nil	0.1	Magnetite
D-7	2.0	92.7	nil	0.1	Magnetite
E-1	44.0	34.7	15.1	4.2	Core
E-2	39.0	56.0	0.4	0.5	Rim

*Analyses were carried out on a JEOL-733 electron microprobe by WDS at 20 kV with a beam current of 15.0 nanoamperes using X-ray lines CrK α , FeK α , TiK α , AlK α , MgK α , MnK α and a chromite standard of known composition.

Table 4. Compositional summary of chromium-bearing minerals

	No. of analyses	FeO range (wt %)	FeO avg (wt %)	Cr ₂ O ₃ range (wt %)	Cr ₂ O ₃ avg (wt %)	Cr/Fe range	Cr/Fe avg
Cr-rich chromite	19	25.4-32.3	29.1	41.0-54.0	45.4	1.2-1.8	1.4
Fe-rich chromite	5	53.5-56.1	54.8	35.9-40.1	38.8	.62-.65	.62
Magnetite	5	90.6-93.8	92.6	0.1-2.0	1.3	-	-

Table 5. Total chromite liberation

Size range μm	Wt % free	Wt % locked (90-99.99% class)	Wt % locked (50-90% class)
-600 +425	0.4	10.2	42.0
-425 +300	0.9	33.9	22.9
-300 +212	3.4	55.7	36.2
-212 +150	4.8	44.3	43.8
-150 +106	11.8	40.1	34.9
-106 +75	16.1	40.2	32.3
-75 +53	27.7	35.5	25.6
-53 +38	34.1	28.3	26.1
-38	37.9	32.4	23.3

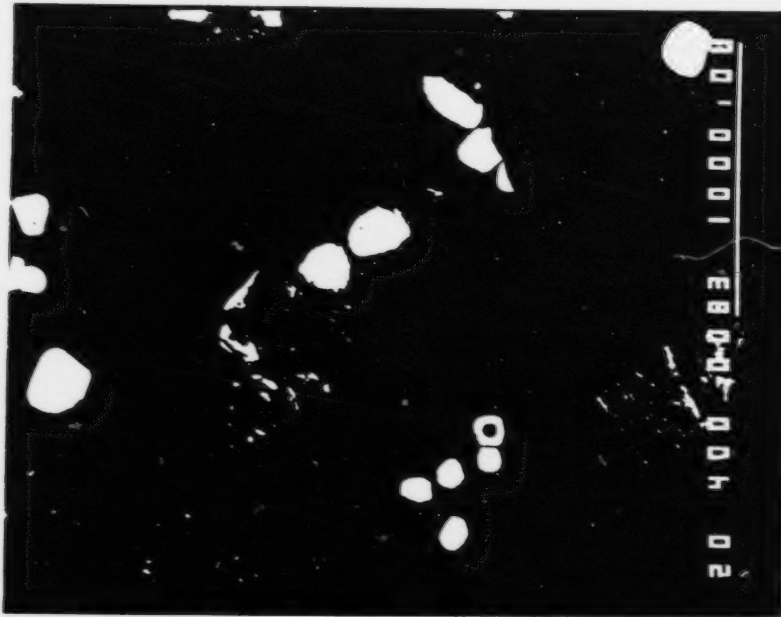


Fig. 1. A backscattered-electron (BSE) photograph shows large rounded chromite grains (white) locked in silicates and also small disseminated grains of magnetite (white) also locked in silicates. The photograph shows that chromite shows no preferential gangue mineral association. One chromite grain at the bottom of the photo has a silicate core.

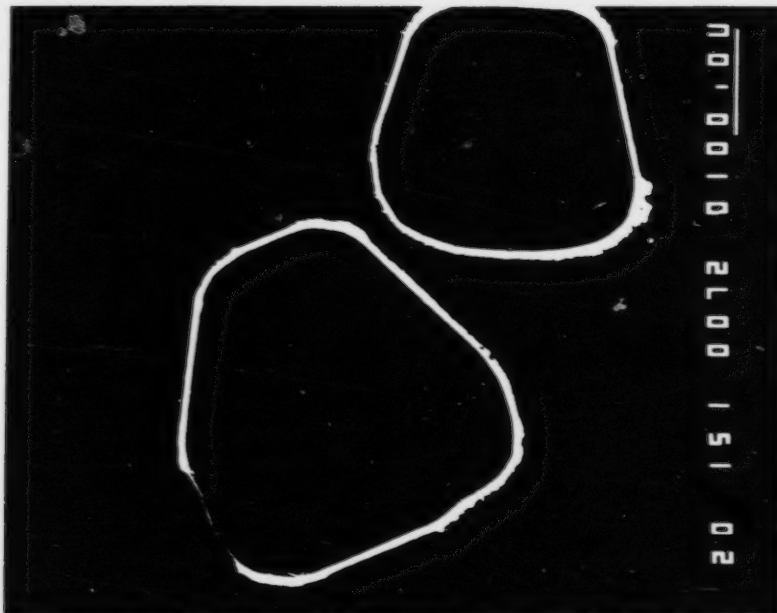


Fig. 2. A BSE photograph of two chromite grains shows the Cr-rich core (grey) and the Fe-rich rim (white). The cores become whiter towards the rims due to a gradual increase in Fe content.



Fig. 3. A BSE photograph of a heterogeneous intergrowth of chromite grains of various Cr-contents. The dark grey areas contain 54% Cr.

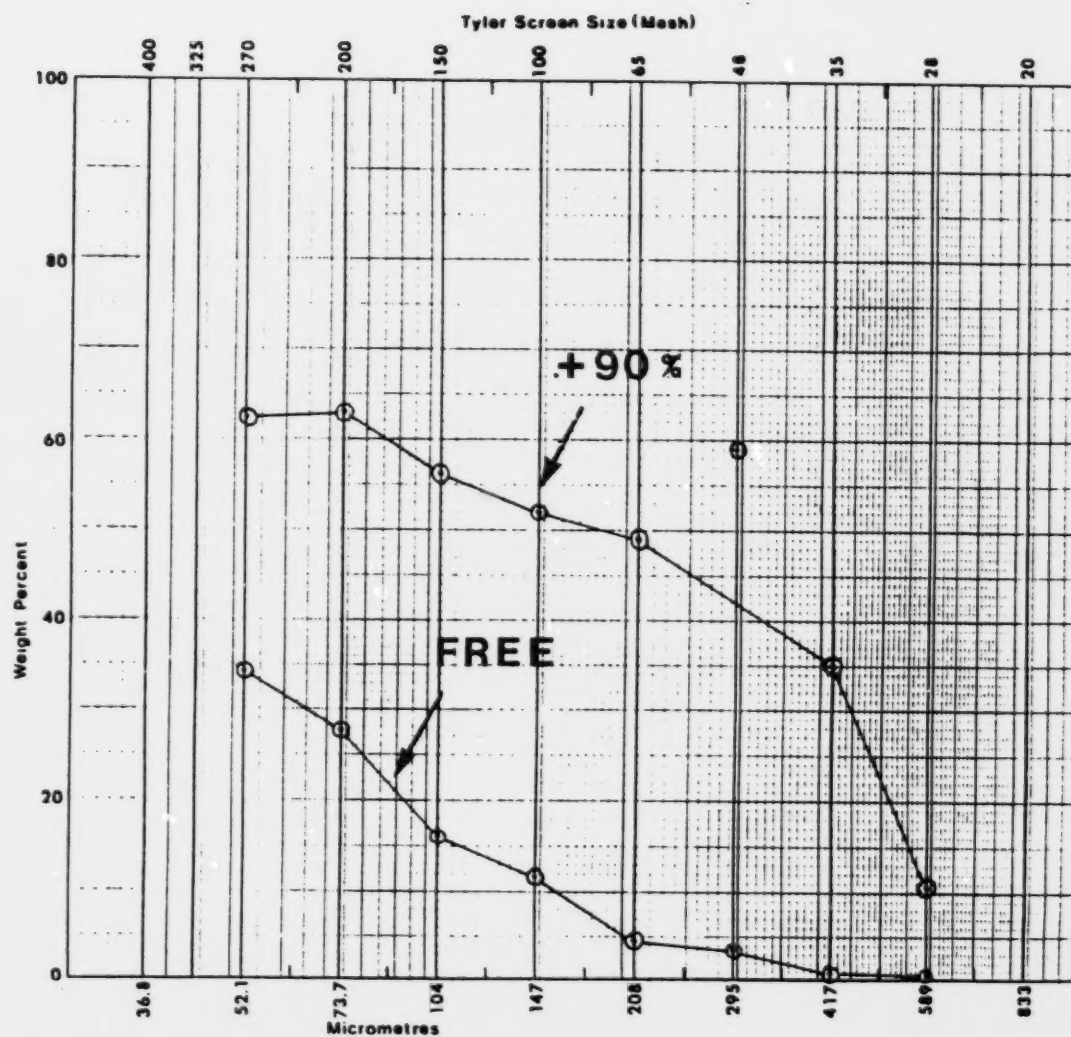


Figure 4. Plot shows completely free chromite and +90% class chromite as wt% of total chromite in each sieve fraction.